



RMHAM microwave relay on Methodist Peak at 11,700 feet. (Photo by Jeff Carrier K0JSC)

Rocky Mountain Ham Radio Microwave Backbone and DMR Repeater Network

By Wayne Heinen N0POH

Use it or Lose it – Making good use of our microwave bands

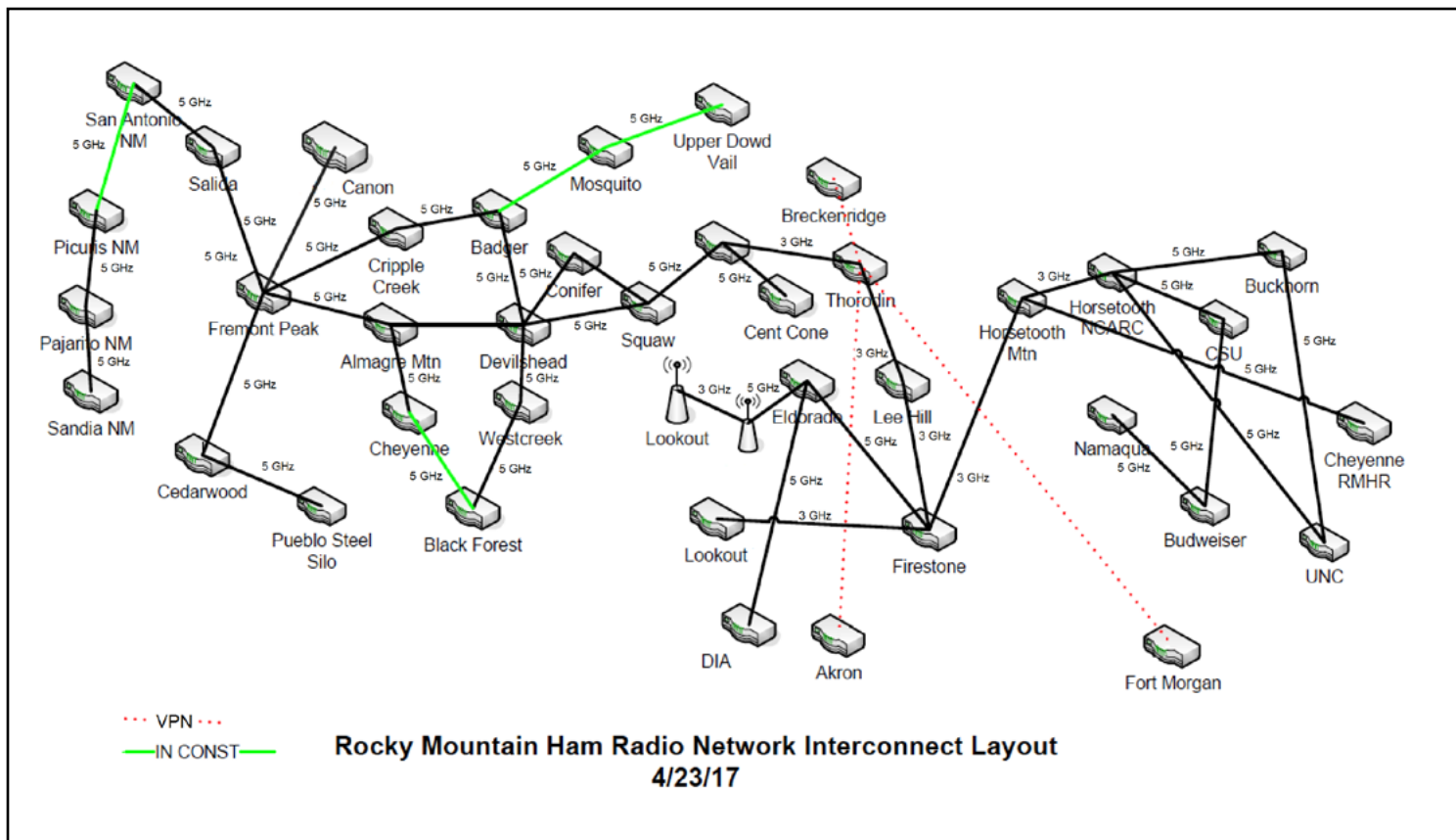
With the advent of all of the new digital technologies, hams have to rely on the Internet more and more for their communications backhaul. Many clubs are moving their linking channels off radio links and onto Voice over IP technology (VoIP). This technology is opening up the world by allowing hams to put repeaters wherever there is access to an Internet connection. Over the last 15 years, VoIP based technologies have been creeping into amateur radio and have firmly taken hold with systems like IRLP, D-STAR, All Star, and MotoTRBO radio systems, just to name a few

Rocky Mountain Ham Radio Inc. (RM Ham) deployed analog repeater sites all along the Front Range of Colorado and had been linking them via IRLP on commercial Internet

for years. Due to the cost and reliability factors of commercial Internet, RM HAM had been looking for a ham radio spectrum-based transport method for their IP needs which have been steadily growing over the years.

RM Ham was a pioneer user of the MotoTRBO technology (also referred to as Digital Motorola Radio or DMR) in Colorado. UHF DMR repeaters were added to a few of RM Ham's analog mountain top sites. These original repeaters were located at sites that had commercial Internet available. The Internet connections cost money and at times had intermittent connectivity. What we needed was a better way to link these repeaters.

What was needed was a digital link that could be created between the various mountain top sites, an IP based



(Courtesy: RMHAM)

network of our own design, which would be controlled by RM Ham as the end user. Current linking of repeater systems in Colorado utilized dedicated UHF analog voice links. The ideal solution was to move higher in the spectrum. The 2.4, 3.4 and 5.7 Gigahertz (GHz) amateur bands are all available for linking however; the available amateur radio equipment is limited to transverters and would require considerable time and effort to construct and configure.

While doing some shopping on the Internet, some interesting items were discovered, including commercially available microwave point-to-point systems that were listed as "For Export Only." They were for export because there are no commercial allocations in the U.S.A. in the portions of the 3 GHz band where these units operate. RM HAM found Ubiquiti Networks, which is a commercial manufacturer that produces radio equipment in the 900 MHz, 2.4 GHz, 3.4-3.8 MHz, 5.2-5.8 GHz and 10 GHz point-to-point and point-to-multipoint IP radio equipment.

This radio equipment can be purchased for export in the 3.3 GHz to 3.5 GHz frequency range and it works perfectly on the ham frequencies where amateurs are the primary licensees. Dealers were very happy to sell us these units after we were able to show them that we were licensed to operate within these bands. The network management tools are impressive for the microwave backbone equipment too. Ubiquiti provides a full network management server that allows you to constantly monitor the signal strength and alarms on any radio connected to the network on any browser as well as an application for iDevices as well as the Android OS.

The next step in the creation of the DMR system is the use of Motorola IP Site Connect (IPSC), this requires a master repeater and can accommodate up to about a dozen peers. Each IPSC on the system is a talk group and is assigned a talk group number. Since we're discussing the creation of the microwave backbone, we'll leave the particulars of the creation of the DMR operating system for another time. A key component of the network is the c-Bridge. The c-bridge is an IP gateway between the repeaters and the network. This allows the backbone control operators to bridge voice and data throughout the multiple IPSC's that are connected on the backbone. The c-Bridge allows the control operators to monitor the traffic on the entire system.

The routers are very important components in the system. They are not only the link between the repeaters and the microwave backbone system but allow RM HAM to remotely control the sites. We have the ability to use the backbone to control our hardware using IP enabled devices. Equipment can be rebooted remotely and power sources can be monitored and switched remotely with IP enabled power distribution equipment. This is very important to RM HAM as most of our repeater sites are either inaccessible or accessible with great difficulty in winter. There have been times when our members have gone in on tracked vehicles and even snowshoed the last ½ mile into some sites.

RM HAM acquired a few microwave units to begin our testing to see if indeed we would be able to use the amateur radio spectrum to build out a suitable network of our own. After a Christmas breakfast in 2009 the group set up



Left: Cripple Creek, at just below 11,000 feet. Center: Rob Wright KC0UUU works on Westcreek. Right: Another view of Westcreek at 9,300 feet. (Photos by Jeff Carrier K0JSC)

two sites in the back of pickup trucks on the north side of the metro area. Tests were made using 3.4 GHz units with two-foot dish antennas and we had success aiming the dishes and obtained very good data rates. Our first link was from Firestone to our Lee Hill site a distance of approximately 22 miles. This confirmed that we could create a backbone to carry our voice and data to our repeater sites. Over the course of a few months we created links to our Mount Thorodin and Squaw Mountain sites. These links comprised the first fully connected repeaters in our DMR system.

Our initial tests and our first links were in the 3 GHz band but there was a drawback as we started to expand and build out our paths. The equipment for 3 GHz proved to be rather expensive and difficult to set up. Our more recent expansion paths operate in the spectrum 5835 MHz – 5925 MHz. This frequency range is not part of the commercial allocation at 5 GHz. The equipment in the 5 GHz band is much easier on the pocketbook.

DMR repeaters use a two-slot time division multiple access (TDMA) scheme supporting two channels per frequency (See *TSM* January 2017 “Scanning America” page 32 for more on this technology) The backbone supports the talk group 700 in time Slot 1 which was called Colorado Wide and was renamed Rocky Mountain Wide, after the inclusion of the New Mexico and Wyoming repeaters to the group. (Figure 1 next page) Talk Group 720 was the Denver Talk Group and has since been renamed Central Colorado Talk Group (Figure 2 next page) since it serves the central part of the state on the I-70 corridor after the addition of repeaters in Breckenridge and Genoa.

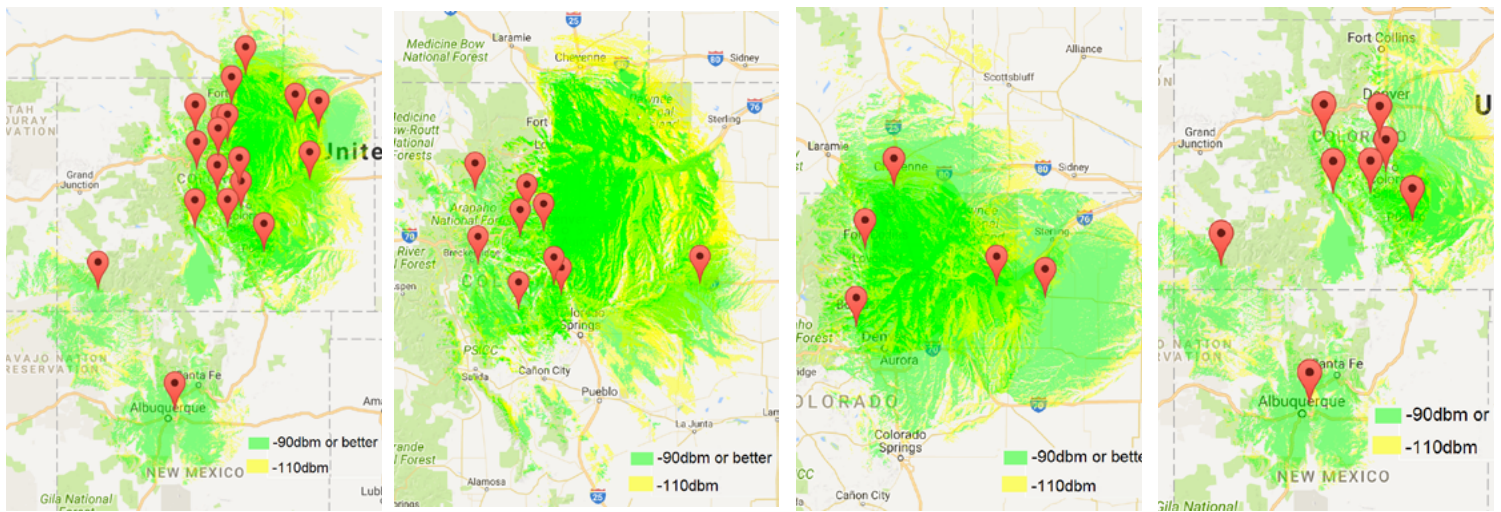
What started as a plan to link a few metro Denver area sites together soon mushroomed. There was considerable interest in the DMR technology and a variety of radios were becoming available, both used and new, at prices that were affordable. Rocky Mountain Ham Radio’s innovative microwave backbone drew interest and some other interested amateurs wanted to help expand DMR sites into their areas.

These amateurs became RM HAM members and “stakeholders” in the buildout of the RM HAM backbone and DMR system. This was a great help as neither repeaters nor microwave units grow on trees. There was a need to “share the load,” both in terms of money and labor, in order for the network to continue to expand throughout Colorado’s Front Range and beyond.

The expansion to the north of the Denver Metro area began with a partner who installed a link back to Firestone from Horsetooth Mountain. In 2015 RM HAM began working with partners in the Northern Colorado Amateur Radio Club and the Colorado State University Radio Club. This allowed the backbone to be extended into the cities of Fort Collins and Greeley. Also, later in that year, a link was established north into Cheyenne, Wyoming, adding another state to the Rocky Mountain Wide Talk Group 700. Talk Group 721 the Northern Colorado Regional talk group is in time slot 2. (Figure 3 next page)

The RM HAM backbone is not 100 percent amateur microwave. There are areas where we have been unable to locate line of sight paths between an existing site and the site that we are interested in expanding to. When this is the case, we still rely on the Internet when it is available. We can establish a VPN (Virtual Private Network) connection between one of our existing sites that has Internet and the expansion site. This was the case when we moved out on the Eastern Plains with our North East All Hazard region partners. We have a VPN to the site in Fort Morgan and VPN links to sites located in Akron and Genoa.

Moving on south of the Denver Metropolitan area, RM HAM established a link between Devil’s Head and Squaw Mountain. This allowed us to link further south to Cheyenne Mountain and Almagre Peak. A redundant path from Devil’s Head to Badger Mountain was created. This path would allow us to work around any outages that might occur on Almagre, which is not accessible in winter. The repeaters located on Almagre have excellent coverage of Colorado



RMHAM microwave backbone up-close: Figures 1-4 (Courtesy of RMHAM)

Springs and the Pike's Peak Region. Badger provides wide area repeater coverage to the South Park Region and the Town of Fairplay. From the Almagre and Badger sites we have links to Fremont Peak. These links connect the backbone to Cañon City, Pueblo and Salida, which gives us DMR coverage for these cities. These repeaters have talk group 720 Rocky Mountain Wide in time slot 1 and talk group 719 the Southern Colorado Regional talk group in time slot 2. (Figure 4 above)

RM HAM has also been able to assist other groups with their linked repeater systems. RM Ham operates what is essentially a UHF digital system. Our partners to the south in Cañon City operate an analog UHF system nicknamed the Fun Machines. The southern portion of the backbone allows the Fun Machines to be linked using the All Star VoIP linking technology. We've also established a link to our central region allowing one of RM HAM's Denver Metro area analog UHF repeaters to join the Fun Machine network. On the VHF side our partners at the Colorado Connection and the Colorado Repeater Association are now using dedicated audio links over the backbone to give a higher quality and more reliable audio streams to their VHF repeaters systems in sites where we have co-located installations.

Some very like minded amateurs from our neighbor to the south became interested in the concepts of our backbone and in the structure of RM Ham, which makes it a different kind of amateur radio organization. They met with us and shared their desire to extend the RM Ham concept to New Mexico. So Rocky Mountain Ham Radio – New Mexico was formed. This group has a DMR repeater in Albuquerque, which is currently linked to Colorado with a VPN. RM HAM-NM is creating a New Mexico backbone that is designed to meet up with the RM HAM Colorado backbone when the link between Picuris Mountain and San Antonio Mountain in New Mexico is completed.

Current expansion plans include linking Badger Mountain to Mosquito Peak and from Mosquito to Upper Dowd overlooking the Vail Valley which will move the microwave portion of the backbone across the Continental Divide and

allow us to find partners to extend to the Western Slope.

Our goal over time was to create a flexible system of repeaters that would be available for general amateur use. This system can be configured to serve groups, such as ARES, who need to supply communications in emergencies to their served agencies. On May 13, 27 men and women, members of RM HAM, volunteered in support of the Broomfield Rotary Club's Triple C Bike Ride. This event raises money for their many charitable causes. They manned the Start/Finish line, rest areas and drove the course. RM HAM's Northern Colorado Regional talk group was utilized for a Rest Area net and simultaneously we used the Central Colorado Talk Group to conduct a Course net. That's what Rocky Mountain Ham Radio is about, Service to Our Community.

About the Author

Wayne's introduction to radio came from his Dad, Bill W2SIC (SK). He became an avid SWL and BCB DXer, joining numerous clubs including the National Radio Club, where he serves on the Board of Directors. First licensed in 1991 Wayne currently holds an Extra class amateur radio license. He became active in many amateur radio clubs in Colorado, and has served as an officer, repeater trustee with the Aurora Repeater Association. He serves as Treasurer and "The Swapfest" chairman for the Aurora Repeater Association, Rocky Mountain Ham Radio Inc. and Cherry Creek Young Amateur Radio Club, as well as Treasurer of the Colorado Council of Amateur Radio Clubs, Colorado's frequency coordination body. He's an avid VHF+ contester and grid chaser, as well as a founding member of Rocky Mountain VHF+ (www.rmvhf.org).

Wayne wrote "Rocky Mountain Ham Radio Communications Trailer" as featured in the May 2014 The Spectrum Monitor and has previously written a variety of feature articles for Monitoring Times the most recent one being "Frequency Coordination in the Amateur Radio Service" (May, 2009) Wayne can be reached at n0poh@arrl.net

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